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Precipitation Verification
8L Model Tests

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I. INTRODUCTION

The following report summarizes the results of precipitation forecasting by the 2° lat-lon 8L Hemispheric model and the 2.5° lat-lon 8L Global model.

The 2° 8L Hemispheric model forecasts from 00Z initial data of each Friday from December 5, 1975, through March 5, 1976, have been run through an 84-hour forecast cycle. The first run was limited to 48 hours and of the remaining ten runs only half reached 84 hours. The results of these eleven cases are presented here.

The 2.5° 8L Global model 24-hr forecasts from final 12Z data have been run regularly since December 16, 1975. All available cases, a total of 90 from December 16, 1975, to May 25, 1976, are summarized here.

The verification area over land includes the United States plus Canada to 50°N except for part of an area in southern Quebec. The 8L model forecasts precipitation within a 2° or 2.5° lat-lon box. A large number of stations in the 60-station network employed by Basic Weather Branch of NMC in their verification program are located near or on the edges of these forecast boxes. The use of this network for verification does not adequately assess the precipitation forecast by the 8L model. In addition, not only is the 60-station network too coarse to adequately represent the actual precipitation occurring it can also negate a reasonable forecast pattern by being overly dependent on a measurable amount at a particular station.

To verify the 8L precipitation forecasts, a network of grid points was chosen. These points represent the center of either a 2° or a 2.5° lat-lon box. If one of the 60 stations fell near the center of the box or if it adequately represented the boundaries (next to Oceans, Mexico) it was chosen instead. There are 167 points in the 2.5° model and 253 points in the 2° version. The increase in the number of points yields a better estimate of the total rainfall distribution and forecast pattern. At the same time one must note that the verification statistics values may not be the same or vary in the same manner as those available from the 60-station network.

II. PRECIPITATION FORECASTING METHOD

Precipitation forecasting in the 8L model results from nonconvective and convective schemes that differ from the methods employed in the present 6L PE model.

The objective of these methods is to extract useful precipitation forecasts within the limitations imposed by the state of the art in simulating cloud and precipitation physics in large-scale models. The prime goal is to fit precipitation forecasts more adequately to the surface circulation and moisture distribution so as to eliminate any disjointed picture in the forecast guidance package.

The nonconvective scheme defines a saturated relative humidity value (SATRH) for each of the moisture forecasting layers (lowest five layers of the six tropospheric model layers) that defines the extent to which evaporation of falling raindrops is permitted. This value is a constant set at 80%. One may also view this criterion as determining the cloudiness content of a layer for other calculations such as radiation.

For precipitation to be initiated, the layer relative humidity must exceed a second criterion (SATQPF). This is a vertically varying value that is equal to or greater than the evaporation criterion.

The layer nearest the ground has a SATQPF value of 100%. This insures that lower level moisture consistent with the mean air temperature is available to upper layers. Also, initiation of precipitation within this lowest layer is virtually eliminated.

The limited test cases run to determine the proper vertical variation in SATQPF resulted in a choice of 90% for the second layer above the lowest layer and 80% for each layer above the second.

Another way of viewing SATQPF is to visualize the difference in RH value with SATRH as cloud droplet growth to precipitation droplet size. Instead of dropping precipitation immediately as in a one criterion scheme like that used in the 6L, we hold on to moisture over a period of time before initiating precipitation and at the same time prevent any restriction to vertical advection of adequate moisture to the next highest layer.

Large difference in SATRH and SATQPF values in the lowest layers and no difference higher up is related to the more rapid growth of droplets to precipitation size in the cold air where ice crystals' existence is most probable.

In the present test results, SATRH is set at a constant 80% for each layer whereas SATQPF varies vertically from the lowest layer upward from 100%, 90%, 80%, 80%, and 80%.

The convective parameterization method employed in the 8L model is designed very simply to estimate the contribution by deep convective storms to precipitation and latent heating of the tropospheric layers. This scheme does not build the instability that is subsequently released by deep convection, but relies on the large-scale determination of conditionally unstable areas with the proper upward motion distribution to release that instability in order to calculate subgrid scale deep convective effects.

III. 2^o LAT-LON 8L HEM MODEL TEST

Table A lists the eleven cases run from December 5, 1975, to March 5, 1976, and their successful forecast hour completion. In the first case, the 8L was restricted to a 48-hr forecast. Subsequent forecasts were scheduled to 84 hours. Only half of the remaining ten cases reached 84 hours.

The next three figures summarize precipitation statistics for the 8L as well as the 6L model. Figure I is for the entire 253 point grid area and is labeled U.S. (for convenience). Figure II is the verification for east of 105^oW (165 points) and Figure III is the verification for the area along and west of 105^{o}W (88 points).

Over the United States, the percentage occurrence of precipitation varied little through the first 48 hours, increased at 60 and 72 hours, and decreased at 84 hours. The 8L precipitation threat score (Ts_p) decreased through 48 hours, remained constant thereafter to 72 hours, and decreased at 84 hours. Six-layer Ts_p showed a maximum at 24 hours, decreased to a minimum at 48 hours, and increased once more to a second maximum at 72 hours.

The Ts_p for both 6L and 8L are similar at 12, 36, 48, and 60 hours. The largest score at 72 and 84 hours by the 6L is due to overforecasting and is reflected in the lower no-precipitation threat score (Ts_{np}). The difference at 24 hours is a real difference in the skill of the models.

The 8L has a dry bias that ranges between 55-60% through 48 hours and 45-50% at the later forecast hours. The 6L starts off dry, holds at about 110% from 24 to 48 hours and ranges from 135-150% in the last three 12-hr periods. The consistently higher Ts_{np} for the 8L is a reflection of its dry bias and the poorer score for the 6L, especially in the later forecast periods, is also a reflection of its bias.

Both post-agreement (PA) and prefigurance (PF) scores indicate the closeness of the precipitation threat scores and the bias. The 8L underforecasts and gets more of what it forecasts, but not enough of the total amount observed. The opposite is true, except at 24 hours, for the 6L.

In Figure II, verification statistics for the area to the east of 105°W show only minor differences with the U.S. variations in the percentage occurrence of rain and Ts_p values for both models. However, while the 8L bias shows the same dryness, the 6L underforecasts, but not to the same degree as the 8L through the first 48 hours, then only slightly overforecasts thereafter. This change in the 6L bias from the overall pattern makes for a closer comparison with the 8L in Ts_{np} and PF values.

Verification statistics for the area west of 105°W (Figure III) reveal striking differences in 6L model performance from that over the eastern United States. Here, we find that after 12 hours the 6L over-forecasts excessively to 84 hours. This large bias increases PF and Ts_p values and lowers PA and Ts_{np} scores. At the same time, the 8L model characteristics appear similar to those over the eastern United States.

Figures IV(a) and (b) show the variation of the bias (observed versus forecast number of points) over the 253 point U.S. verification area for each forecast period. A bias of 100% is indicated by the radiating center line whereas a bias of 200% and 50% is represented by the upper and lower lines respectively.

The dry bias of the 8L model holds true for all ranges of precipitation occurrence from very light to heavy for all the forecast periods. The 6L shows only slight variation in its distribution for the first 36 hours and at 84 hours. However, for 48, 60, and 72 hours the 6L forecasts similar number of points regardless of whether the observed condition had very light or moderate to heavy rainfall. At the same time, for light to moderate observed conditions, the 6L bias was not excessive.

IV. 2.5^{o} LAT-LON 8L GLOBAL MODEL TEST

The 2.5^{o} lat-lon 8L Global Model test is composed of 12-hour precipitation forecasts from 24-hour forecasts verifying at 12Z from December 16, 1975, to May 25, 1976. These cases are compared with the 6L and LFM forecasts. Note that both the 6L and LFM achieve their maximum Ts_p at this verification time.

The verification utilizes both the 60-station network (actually 59 stations since Regina does not appear in the point grid network) as well as a 167-point grid system. Also, the areas to the west of and east of 105^{o}W have been analyzed separately.

Figure V(a) plots Ts_p versus bias for the United States, West- and East-105^{o}W, for the three models, and the two verification systems. The difference between the statistics using the two verification grids is most apparent for the 8L. The 167-point statistics will be used in the subsequent comparison, but conclusions for the 6L and LFM are also supported by the 60 station results.

For the United States, Ts_p for all the models vary within two to four points whereas their individual biases vary greatly. Six-layer bias is largest at 112% and the LFM underforecasts at 84% while the 8L more so at 65%. This average picture over the United States is derived from rather striking differences in model biases by both the 6L and LFM over the western and eastern parts of the United States.

Over both the eastern and western United States, the difference between model Ts_p is from two to four points with the 6L having the best score. Over the western United States, however, the 6L over-forecasts at 167% and the LFM at 143%. The 8L bias is 85%. For the eastern United States, all models underforecast with the 8L at 56%, the LFM at 61%, and the 6L at 84%.

The parallel performance in Ts_p and differing biases yield the following picture in PA and PF (Figure V(b)). In the east, PA is larger than PF since all the models underforecast. In the west, over-forecasting by the LFM and 6L yields much larger PF than PA values whereas the 8L pattern is similar to that over the eastern United States.

The overall U.S. pattern shows how the averaging of diverse behavior over different areas of the United States conceals the actual performance of the 6L and LFM models.

The next two figures show the variation of threat scores and bias within various percentage rainfall categories. The average for the entire test period is also repeated here for comparison.

Figure VI(a) is for the area east of 105°W (110 points). All the models are underforecasting, but the 6L to a lesser degree than the others. As a consequence, the 6L is slightly better in all respects with the LFM and 8L trailing in that order. The models were identical in the 15-20% category where the maximum number of cases were observed. Also, even though the models underforecast on the average, the degree of underforecast was ameliorated as percentage rainfall occurrence increased.

Figure VI(b) is for the area to the west of 105°W (57 points). Ts_p for 6L and LFM differ by two points. Both overforecast by large amounts in light rainfall cases, but stabilize to 150% for the 6L and 120-130% for the LFM for those situations with more than 15% coverage. The 8L on the other hand consistently underforecasts except for the 5-10% category. It does remarkably well in Ts_p for the light rainfall categories (0-15%) where 46 of the 90 total cases occur. In the heavier precipitation cases the larger Ts_p of the 6L and LFM over the 8L is a reflection of their biases and is offset by the larger Ts_{np} of the 8L.

Threat scores and biases over the east, west, and entire United States by months (December to May) and seasons (winter and spring) for the 8L, 6L, and LFM are depicted in Figures VII(a), (b), and (c) respectively. The most striking feature in these figures is the variation in the bias over the western United States for both the 6L and LFM. From winter to spring, 6L bias decreased by 50% with a range of 141% in monthly biases. LFM values were 54% and 105%, whereas for the 8L the values were 1% and 44%, respectively. It should be noted that the saturation criterion for precipitation in the LFM is decreasing linearly in time in the spring months to 90% from the constant 96% value employed during the winter.

Over the eastern United States, monthly and seasonal changes were not unusual. The overall U.S. distribution for the 6L and LFM reflects the change in the western bias discussed above.

Post-agreement and pre-figurance variations by months and seasons are shown in Figures VIII(a) and (b). In addition, average rainfall occurrence and number of forecasts are indicated in Figure VIII(b).

Over the eastern United States, convective precipitation increased during the spring months. Decrease in PA scores from winter to spring reflect this change. Over the western United States, the sharp change in PF for the 6L and LFM is due to the change in bias discussed earlier.

The patterns show that the LFM looks like the 6L in the west and looks like the 8L in the eastern United States. Forecast characteristics change completely between the west and east for both the 6L and LFM. As a result, the overall U.S. distribution does not serve as an indicator of actual model performance. The 8L performs in a similar fashion over both the western and eastern United States so that the overall pattern describes its characteristics. There is some difference in the west because the underforecasting there is not of the same degree as that in the east. The reason for this difference will be discussed in the last section.

Finally, in Figure IX we have the 8L convective forecasts summarized by months, seasons, and for the test period. These forecasts represent those precipitation points predicted exclusively by the convective method. Changes to both bias and Ts_p over west and east United States without this contribution are also indicated.

Convective precipitation forecasting occurred principally in the spring. Over the eastern United States, the 8L was nearly 40% correct. This success rate contributed to the Ts_p. These forecasts add approximately 15% to the bias.

Over the western United States, the convective method was not so successful. However, although about 25% correct for spring, in May there was a positive contribution to Ts_p and nearly a 40% contribution to the bias.

V. DISCUSSION

The 2° lat-lon 8L forecasts were also subjectively evaluated at 24, 48, and 84 hours. Four meteorologists in Forecast Division conducted this evaluation which included five additional cases that were run after March 5. The result of their evaluation indicated that the 8L was about the same as the 6L at 24 hours and a little better at 84 hours.

The result of the objective evaluation showed that the 6L had a larger Ts_p for both these forecast periods. This difference between the subjective and objective evaluation suggests that Ts_p is not an adequate indicator of the usefulness of precipitation forecasts when used by itself. We have seen that the 6L model behaves radically differently in different parts of the United States. It appears that the severe overforecasting in the west detracts from the usefulness of the forecast in the east. This inconsistency in performance, especially at 84 hours, is distracting in a subjective evaluation.

The 8L has a more consistent performance over both sections of the country. And, in spite of its dry bias the Ts_p is competitive--implying that along with its large PA score there was value to the precipitation forecast pattern when subjectively evaluated.

The dry bias character of the 8L also extends over all forecast periods while the 6L bias over the west grows in time. And, although the 8L underforecasts for all rainfall situations it does so to a lesser extent as percentage rainfall occurrence increases.

The 24-hour 2.5° lat-lon 8L forecast evaluation was also done subjectively. The first 9 cases, all in December, were evaluated by five meteorologists in the Quantitative Precipitation Branch. The results (not shown here) also indicate that Ts_p by itself in individual cases does not reflect usefulness of precipitation forecast patterns.

The objective results reveal similar characteristics to that shown in the 2° tests. We find that in spite of its dry bias the 8L remains competitive in Ts_p at 24 hours when both the 6L and LFM have Ts_p maxima.

The monthly and seasonal variation in performance indicated a sharp change in forecast bias over the western United States going from winter to spring for both the 6L and LFM. The 8L did not have this seasonal change.

The 8L dry bias does not vary radically by months or season. This is true even with the change in precipitation character with season. Analysis of the convective contribution to precipitation forecasting in the 8L shows that there is an increasingly larger contribution to the total bias during the spring months. This result suggests that the non-convective and convective schemes tend to be complementary.

The convective scheme was designed to parameterize well-organized deep convection. As such, the conditions required to set off the method are restrictive. This should result in a dry bias. This implies that both convective and nonconvective methods employed in the model under-forecast.

This verification test does not indicate anything about 8L precipitation forecasting over the oceans. Over water, copious amounts of rainfall are possible contributing to excessive storm development. This is also often true near water-land boundaries such as the west coast. Note that this problem is one of excessive precipitation in a grid box or two, and not one of excessive areal forecasting.

This difficulty is more directly related to evaporation processes in the lowest model layer. Experiments restricting evaporation flux over water significantly altered precipitation amounts and spurious storm development. Along the west coast, precipitation forecasts and patterns were also drastically altered. There is no doubt that evaporation flux is crucial to the model forecast, but it was overestimated in these test forecasts. This result suggests that it is this contribution that leads to the slightly higher overall bias for the western United States from that over the east.

Finally, even though the 8L underforecasts, it does so consistently over the entire United States for all forecast periods and over the total range of rainfall situations. In tuning the model precipitation, it is hoped that the bias can also be increased uniformly without significant loss in PA scores. The following adjustments to the precipitation forecasting schemes are contemplated:

(1) Evaporation flux in the lowest model layer will not be permitted if the layer relative humidity equals or exceeds SATRH. The wetness parameter that controls the degree of flux will also be adjusted.

(2) The vertically varying SATQPF values in the second and third layers above the surface will be a function of the layer temperature (warmer(colder) temperature with higher (lower) saturation values). As such, it will vary over the hemisphere from point to point. This should tend to increase the overall bias by increasing precipitation in the cold air and decreasing it in the warm air. Furthermore, this would eliminate any need to seasonally adjust the SATQPF criterion.

(3) The convective scheme will be more thoroughly examined during the warm season.

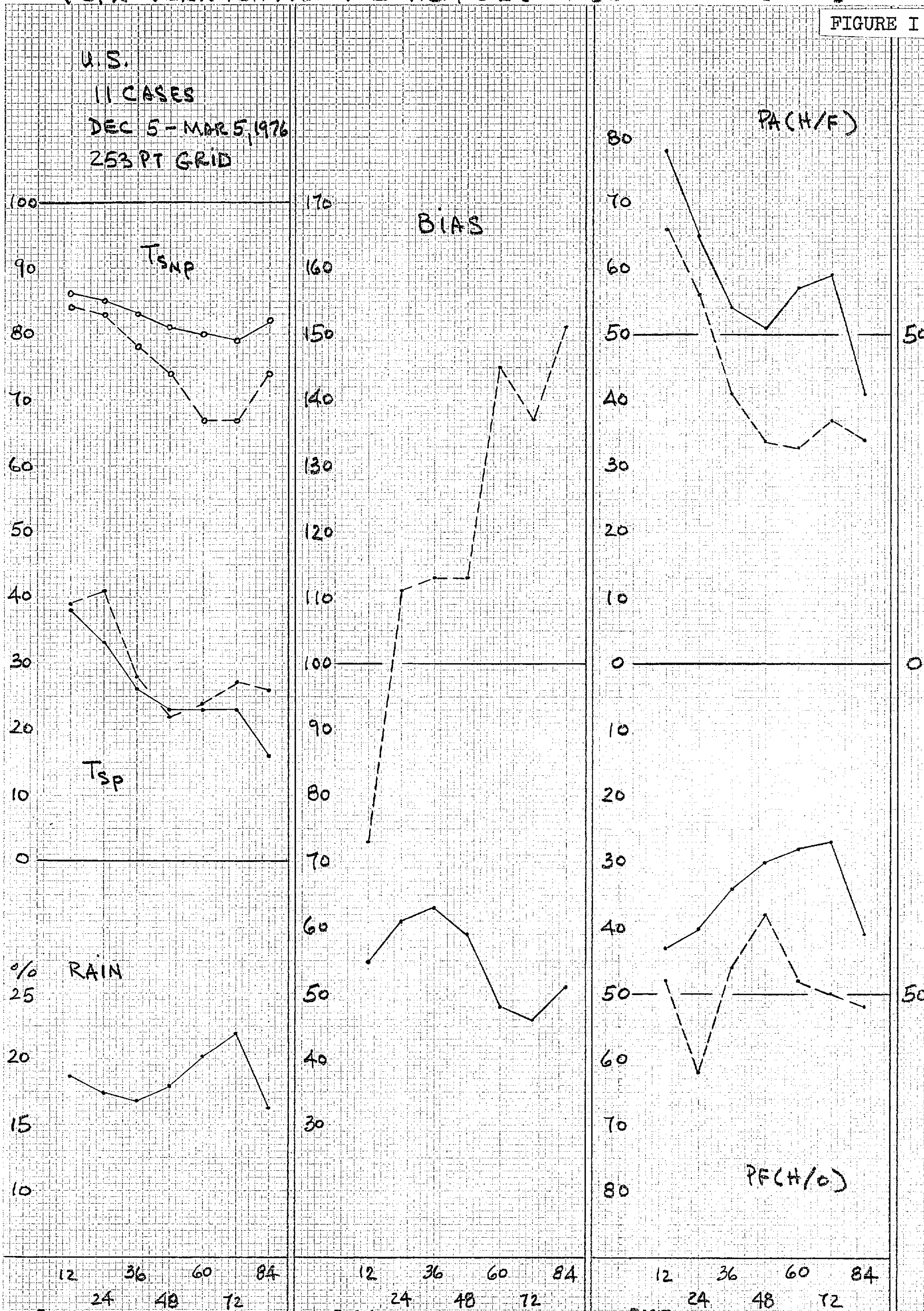
TABLE A

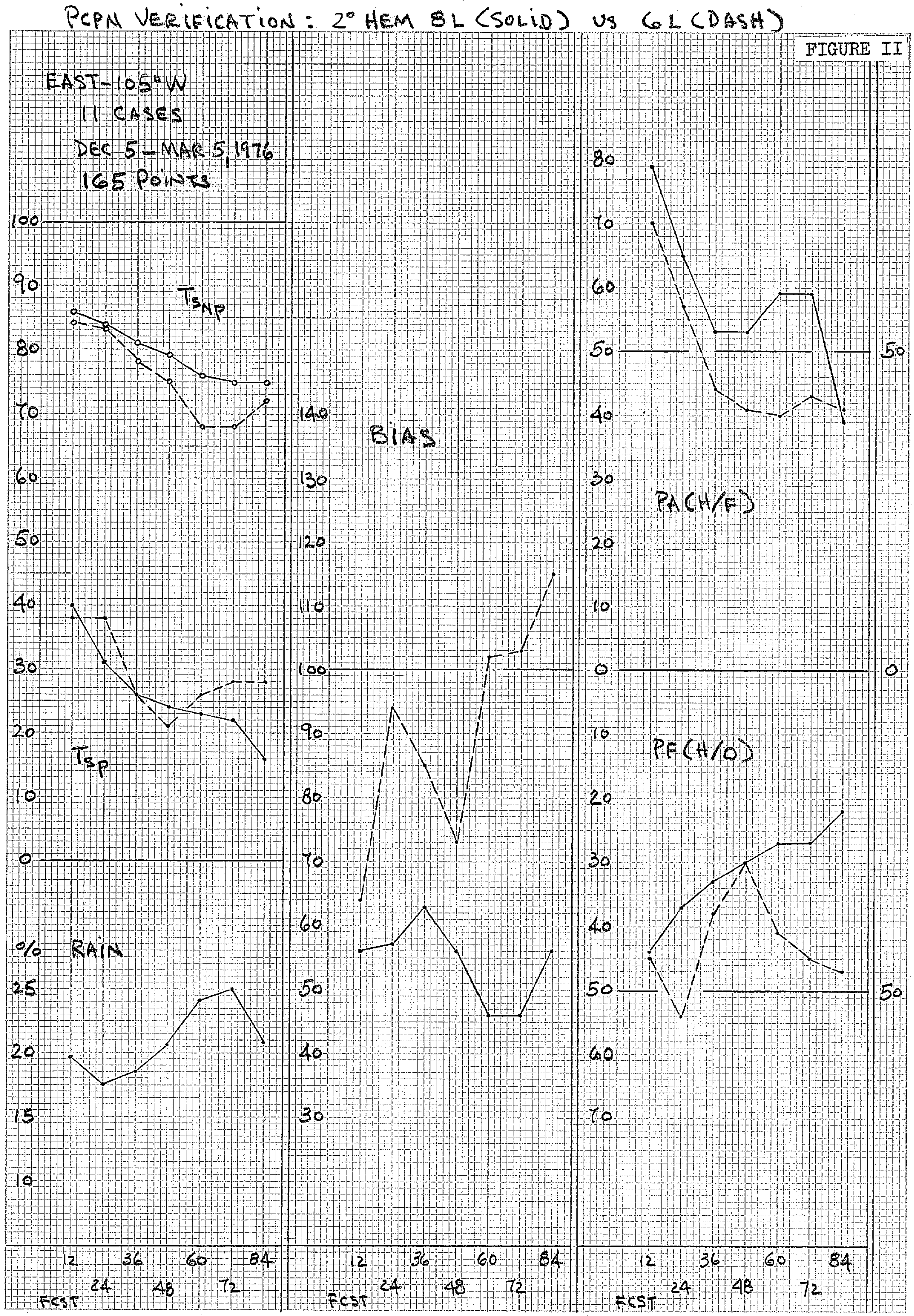
2° lat-lon 8L HEMISPHERIC model cases

CASE	DATE	FCST COMPLETED
1.	Dec. 5, 1975	48-HR
2.	Dec. 12	72-HR
3.	Dec. 19	72-HR
4.	Dec. 26	84-HR
5.	Jan. 9, 1976	84-HR
6.	Jan. 16	84-HR
7.	Jan. 30	84-HR
8.	Feb. 6	72-HR
9.	Feb. 20	84-HR
10.	Feb. 27	72-HR
11.	Mar. 5	72-HR

PCPN VERIFICATION: 2° HEM 8L (SOLID) VS 6L (DASH)

FIGURE I




PCPN VERIFICATION: 2° HEM 8L (SOLID) VS 6L (DASH)
FIGURE II
EAST-105°W
11 CASES
DEC 5 - MAR 5, 1976
165 POINTS
T_{SNP}
T_{SP}
RAIN
%
BIAS
PA(H/F)
PF(H/O)
FCST
12 24 36 48 60 72 84

PCPN VERIFICATION: 2° HEM 8L (SOLID) VS 6L (DASH)

FIGURE III

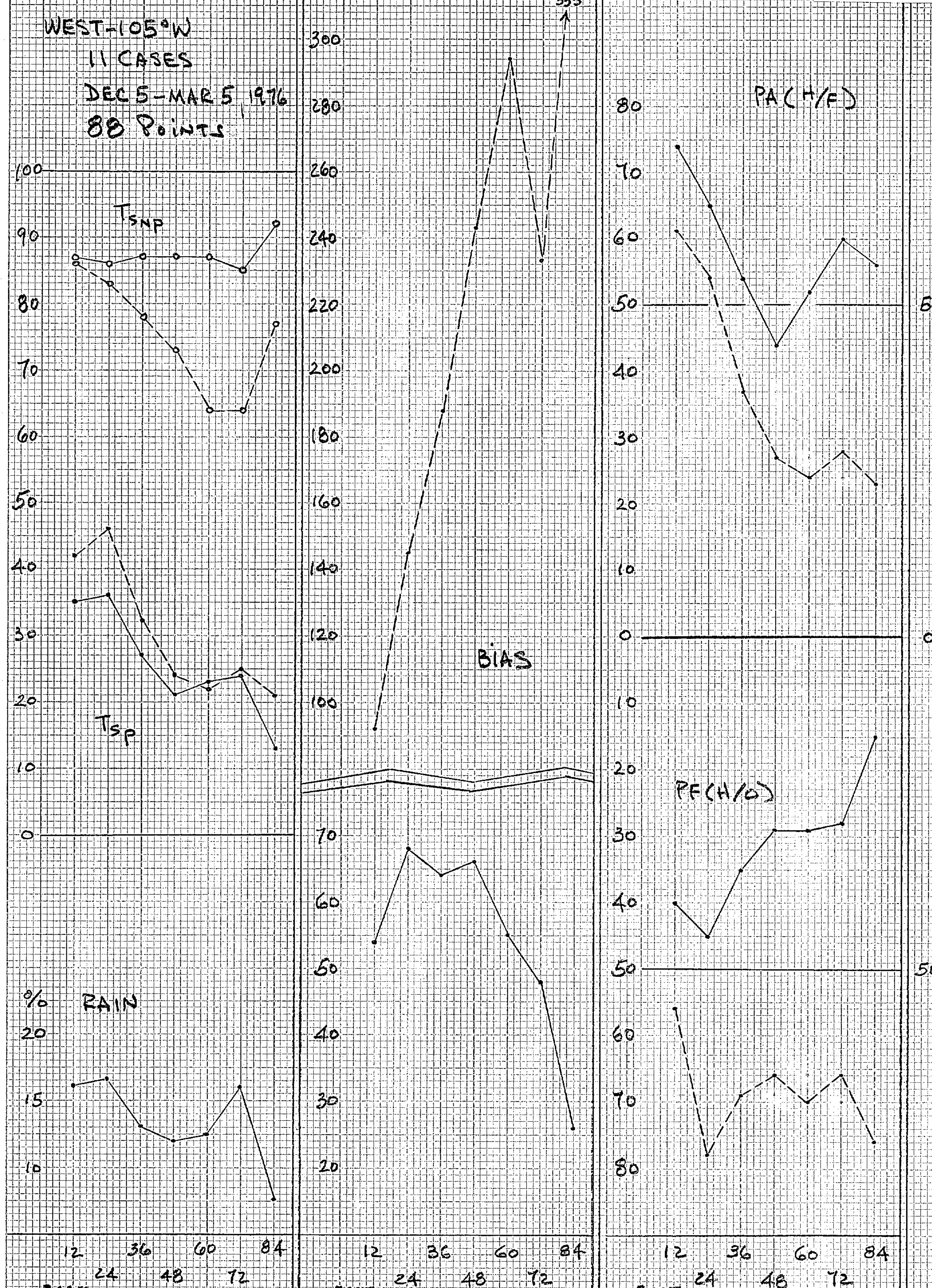


FIGURE IV(a)

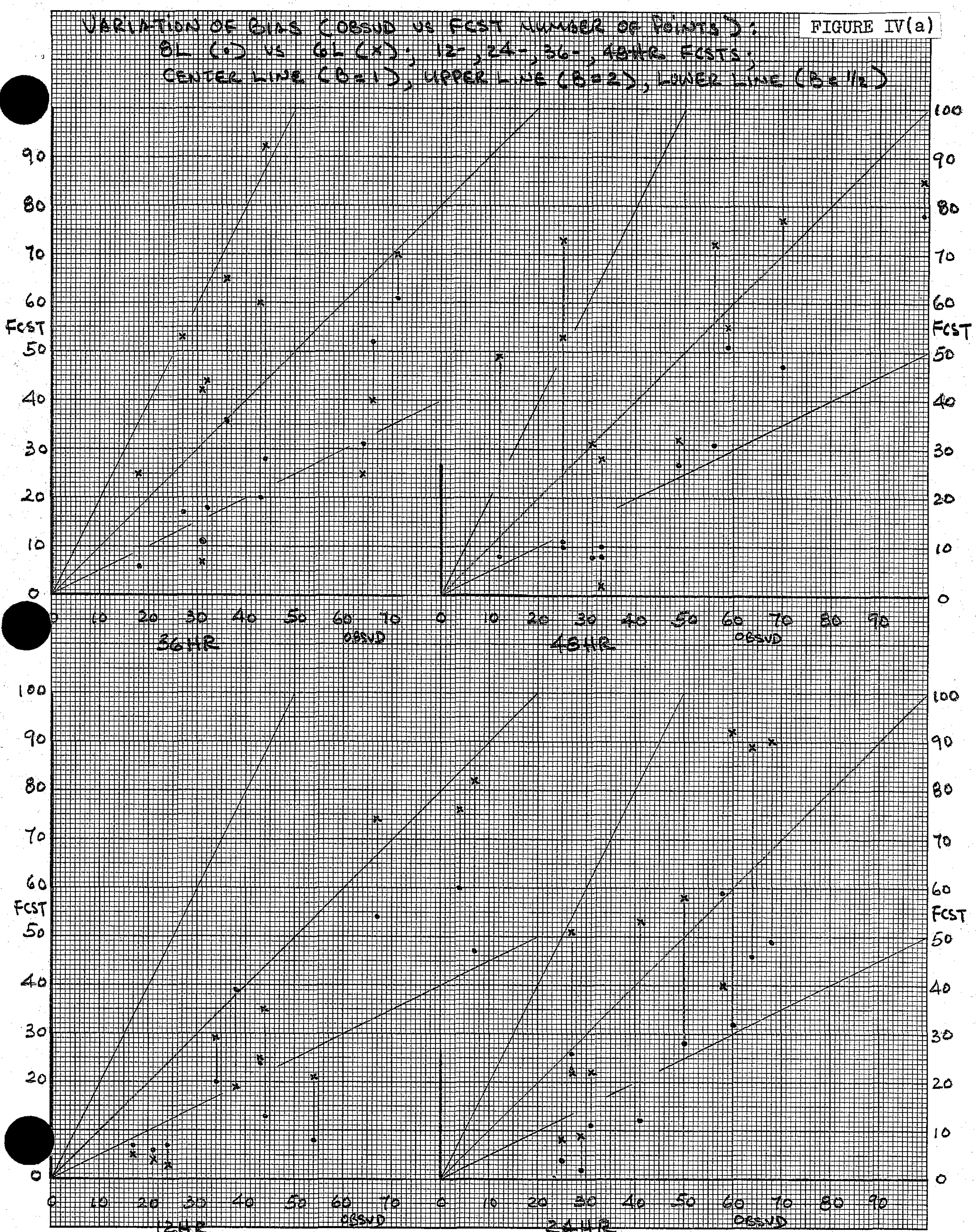
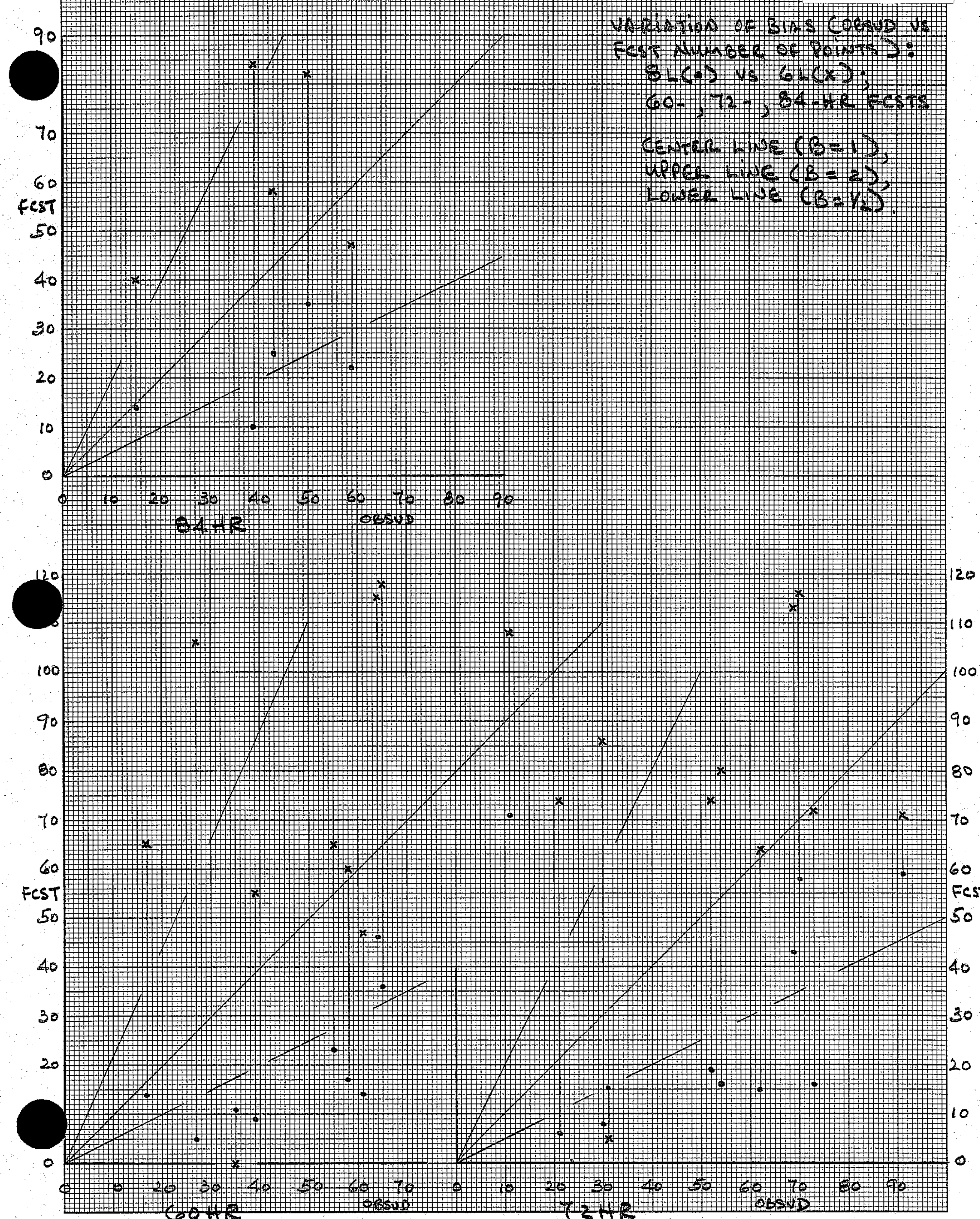

VARIATION OF BIAS (OBSVD VS FCST NUMBER OF POINTS):
8L (•) VS 6L (x); 12-, 24-, 36-, 48HR FCSTS;
CENTER LINE (B=1), UPPER LINE (B=2), LOWER LINE (B=1/2)
FCST
OBSVD
36HR
48HR
12HR
24HR

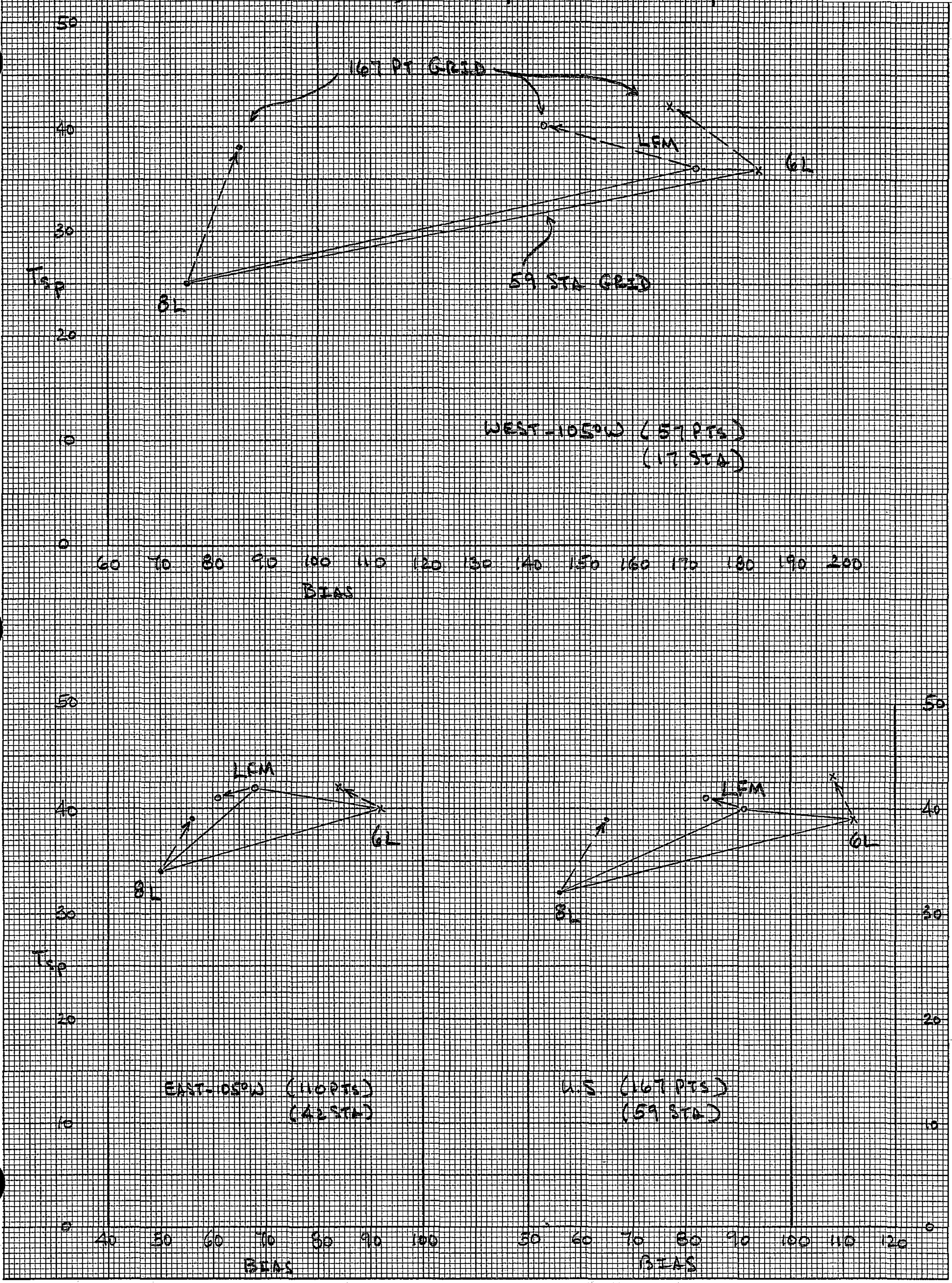
FIGURE IV(b)



10 X 10 TO THE CENTIMETER 18 X 25 CM.
UNITED CONVERTERS & PRINTERS

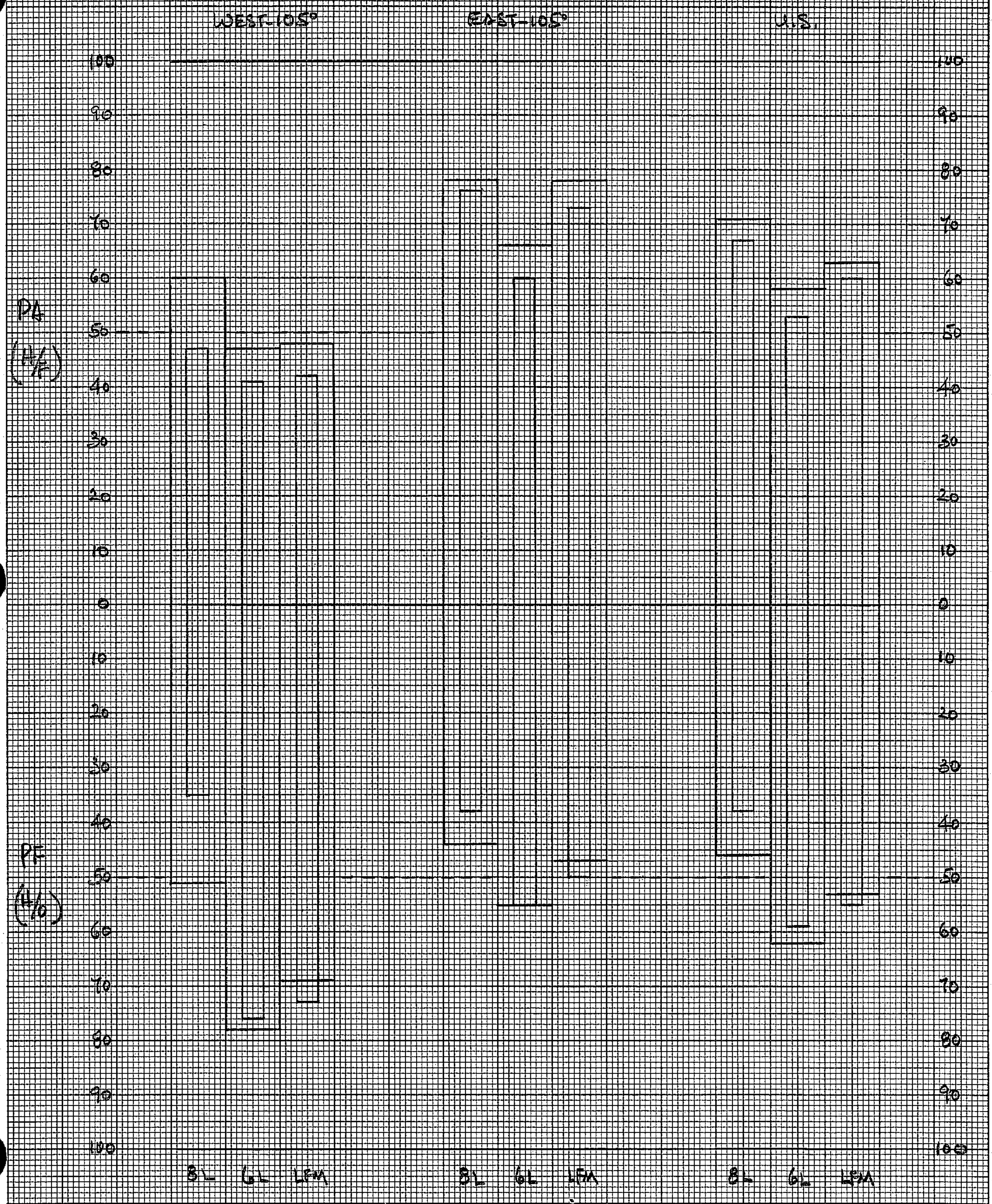
PCPN VERIFICATION: 12HR PCPN; 24-HR FCST; V.T. 00-12Z; 2.5° BL
90 CASES (88 FOR 6L); DEC. 16, 1975 TO MAY 25, 1976

FIGURE V(a)



PCPN VERIFICATION: 12 HR PCPN; 24 HR FCST; U.T. 00-12Z; 2.5° 8L
90 CASES (88 FOR 6L); DEC 16, 1975 TO MAY 25, 1976

FIGURE V(b)



OUTER RECTANGLE: 167 PT. GRID   INNER RECTANGLE: 59 STATION

FIGURE VI(a)

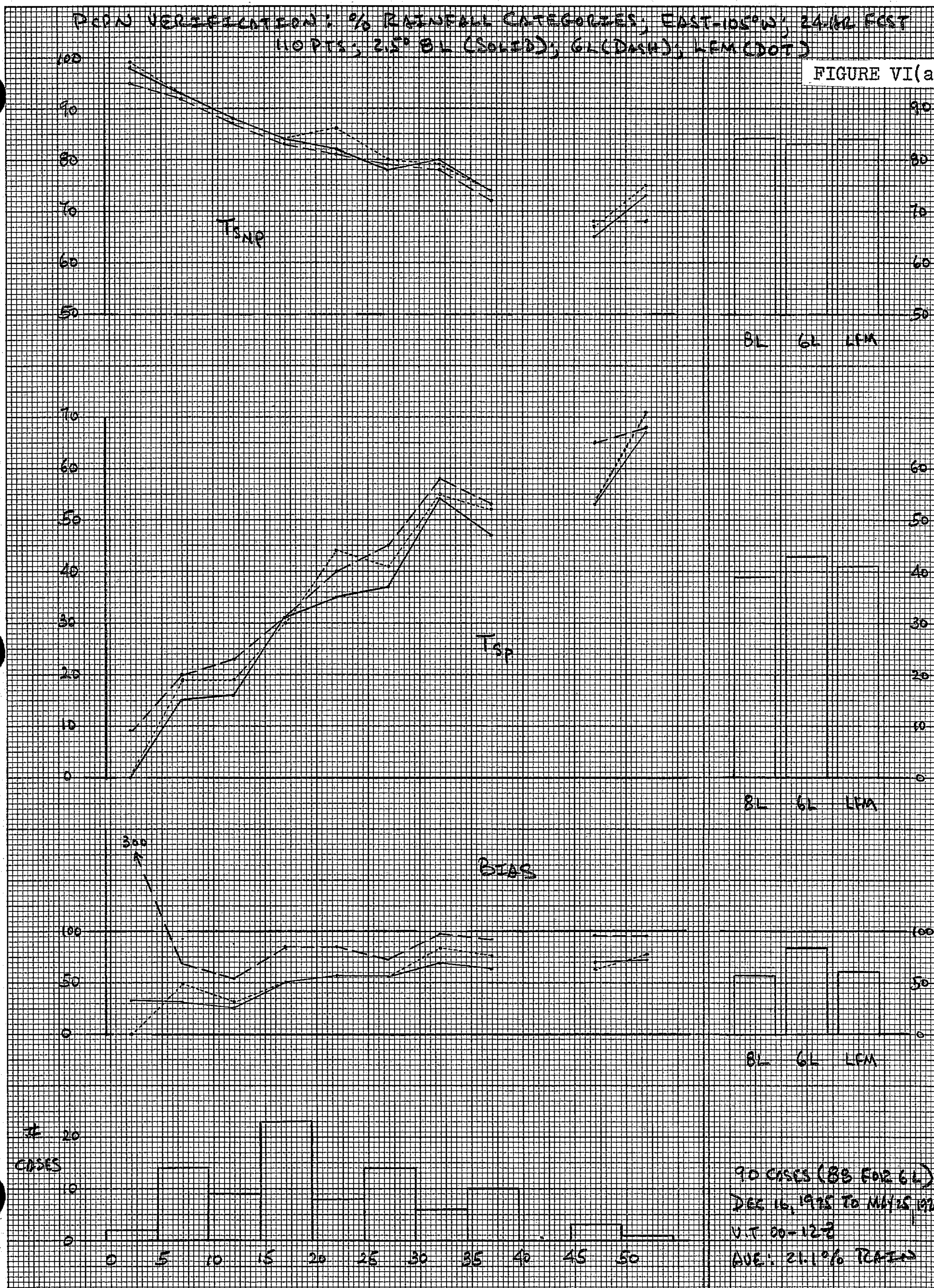
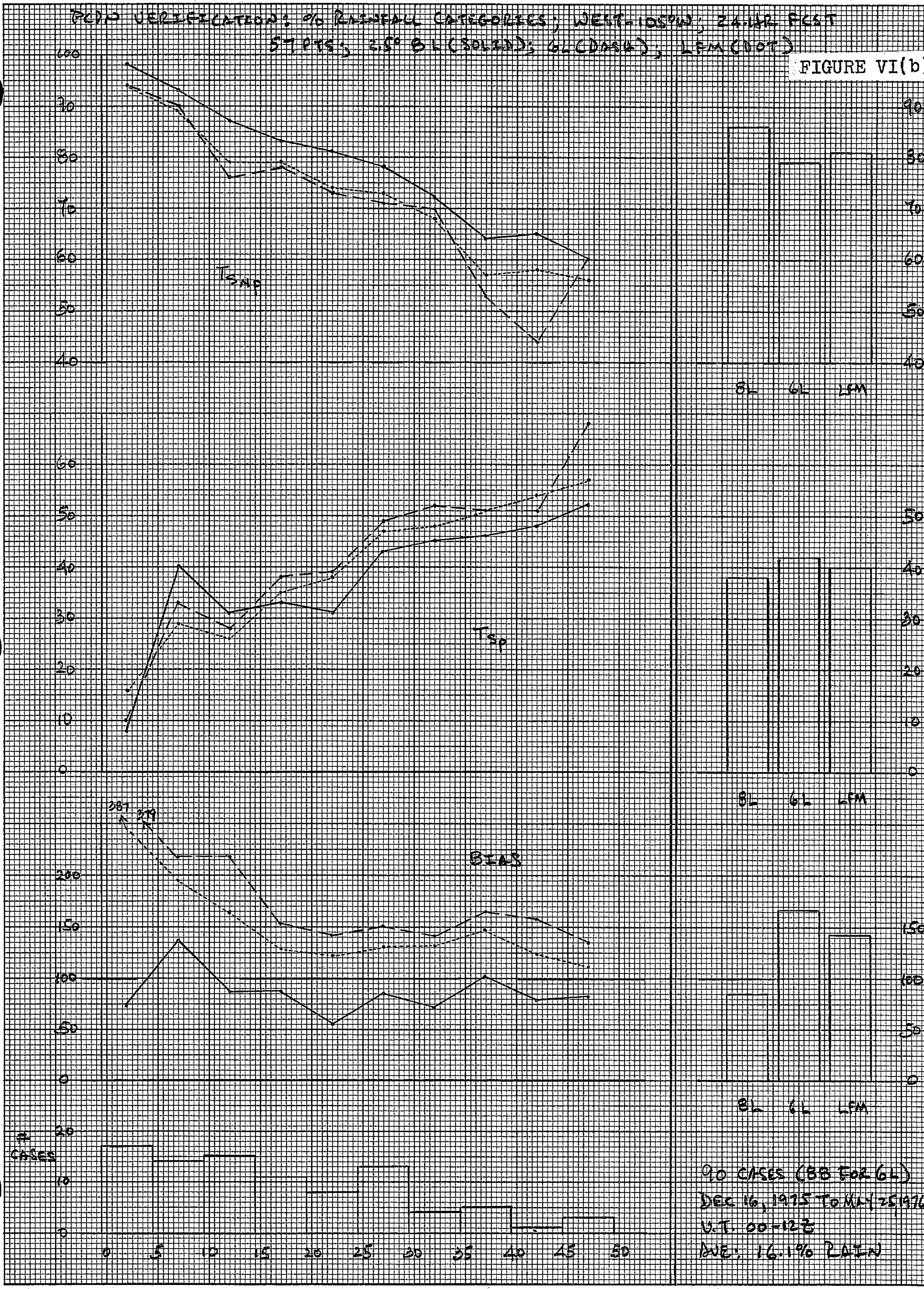

PQPN VERIFICATION: % RAINFALL CATEGORIES; EAST-105°W; 24-HR FCST
110 PTS; 2.5° 8L (SOLID); 6L (DASH); LFM (DOT)
TSNP
8L 6L LFM
TSP
8L 6L LFM
BIAS
300
8L 6L LFM
CASES
90 CASES (88 FOR 6L)
DEC 16, 1975 TO MAY 25, 1976
V.T. 00-12Z
AVE.: 21.1% RAIN

FIGURE VI(b)



PCPN VERIFICATION: % RAINFALL CATEGORIES; WEST-105°W; 24-HR FCST
57 PTS; 2.5° 8L (SOLID); 6L (DASH); LFM (DOT)
TSMP
TSP
BIAS
381
379
CASES
8L
6L
LFM
90 CASES (88 FOR 6L)
DEC 16, 1975 TO MAY 25 1976
U.T. 00-12 Z
AVE: 16.1% RAIN

FIGURE VII(a)

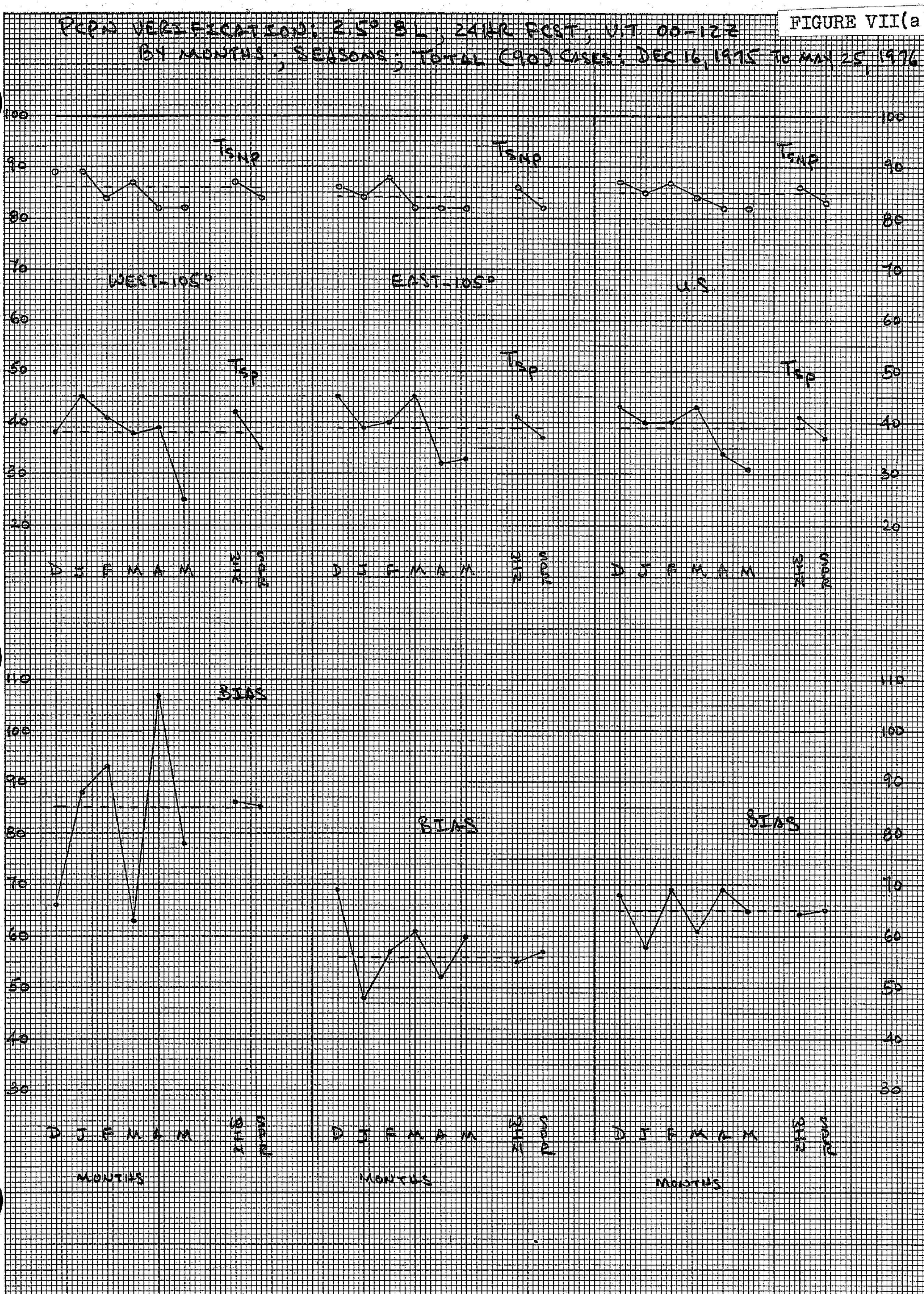
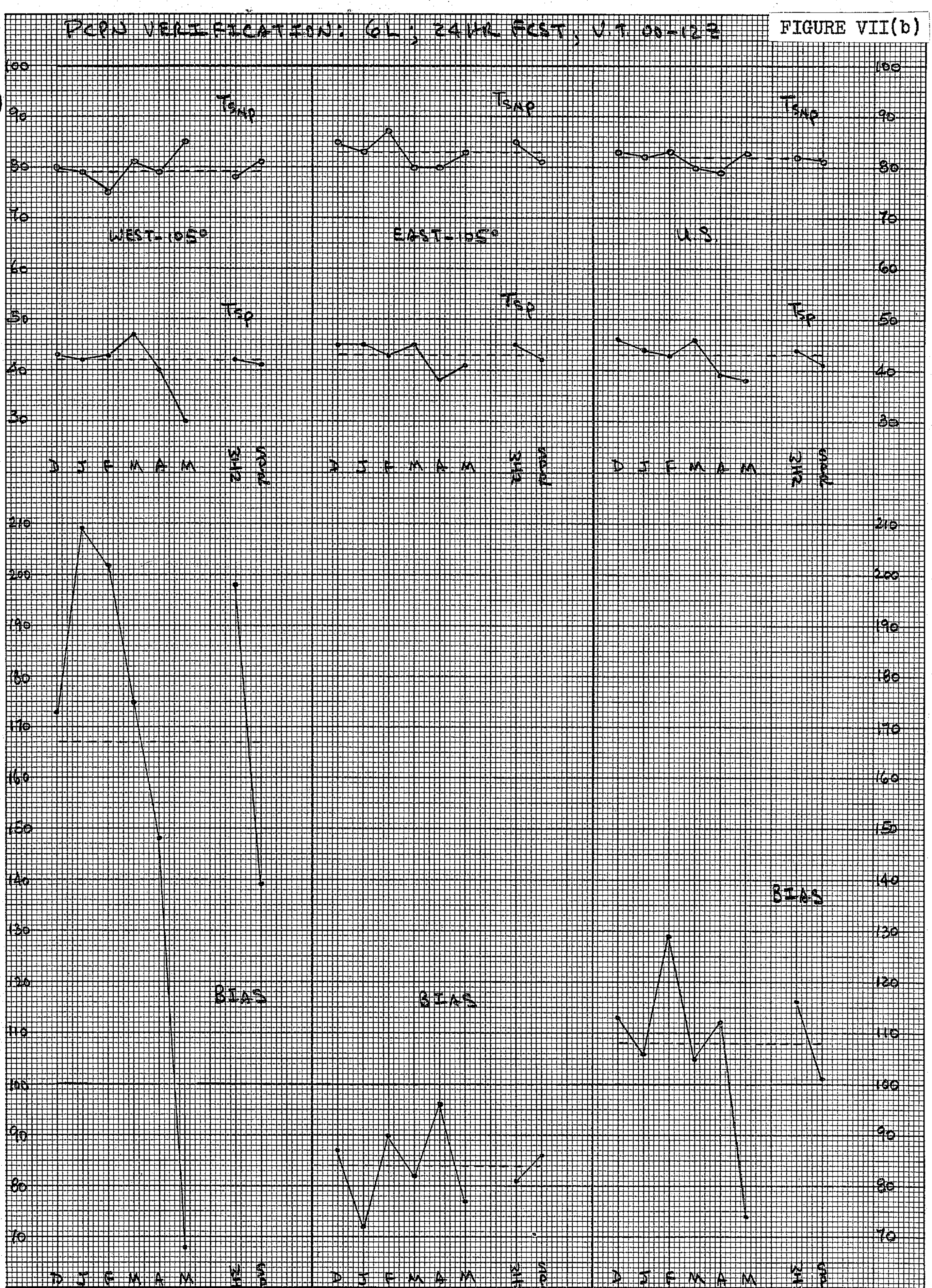
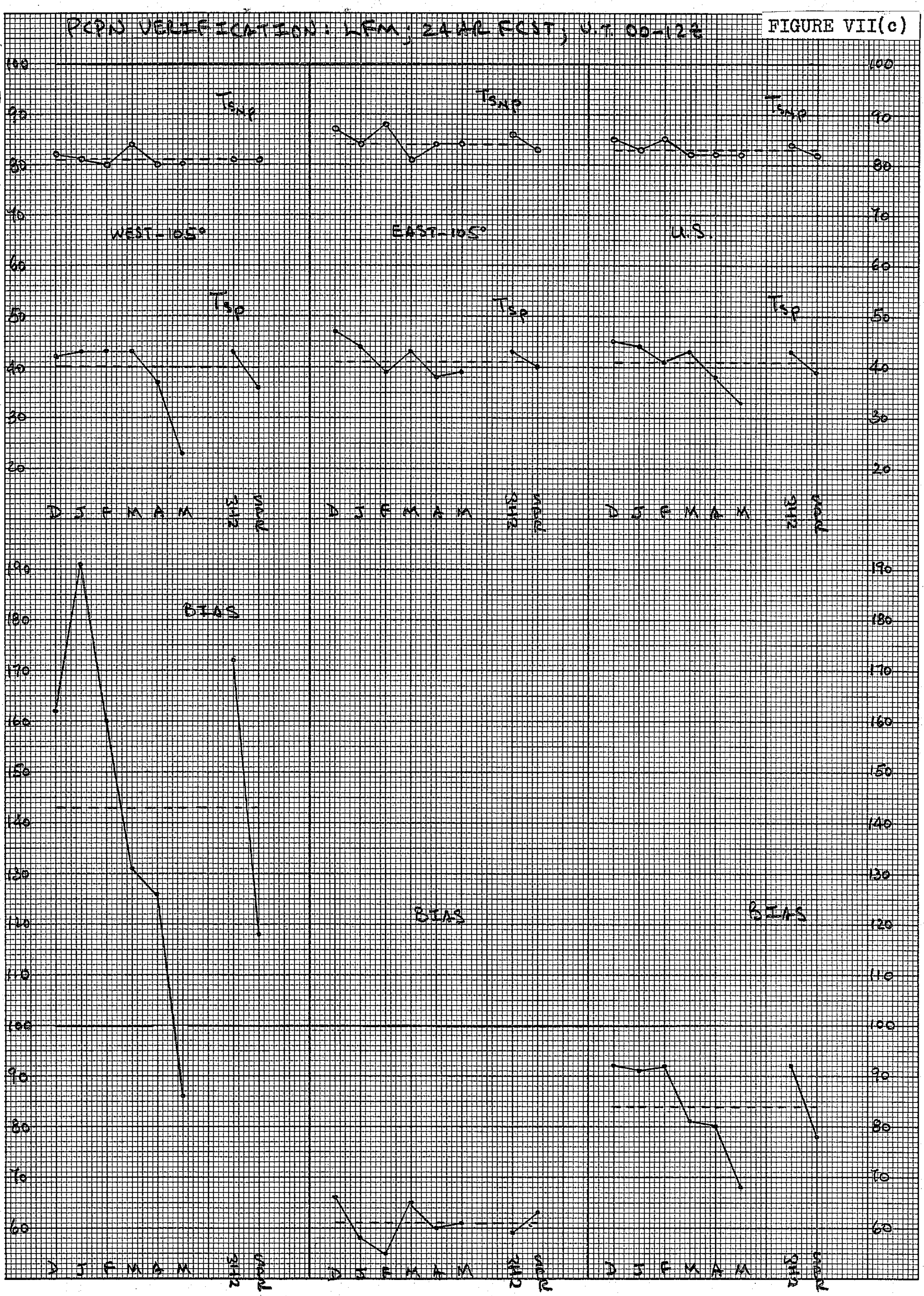

PCPN VERIFICATION: 2.5° BL; 24HR FCST; V.T. 00-12Z
BY MONTHS; SEASONS; TOTAL (90) CASES: DEC 16, 1975 TO MAY 25, 1976
TSNP
WEST-105°
EAST-105°
U.S
TSP
BIAS
D J F M A M
WIN
SPR
MONTHS

FIGURE VII(b)



10 X 10 TO THE CENTIMETER 18 X 25 CM.
UNITED CONVERTERS & PRINTERS

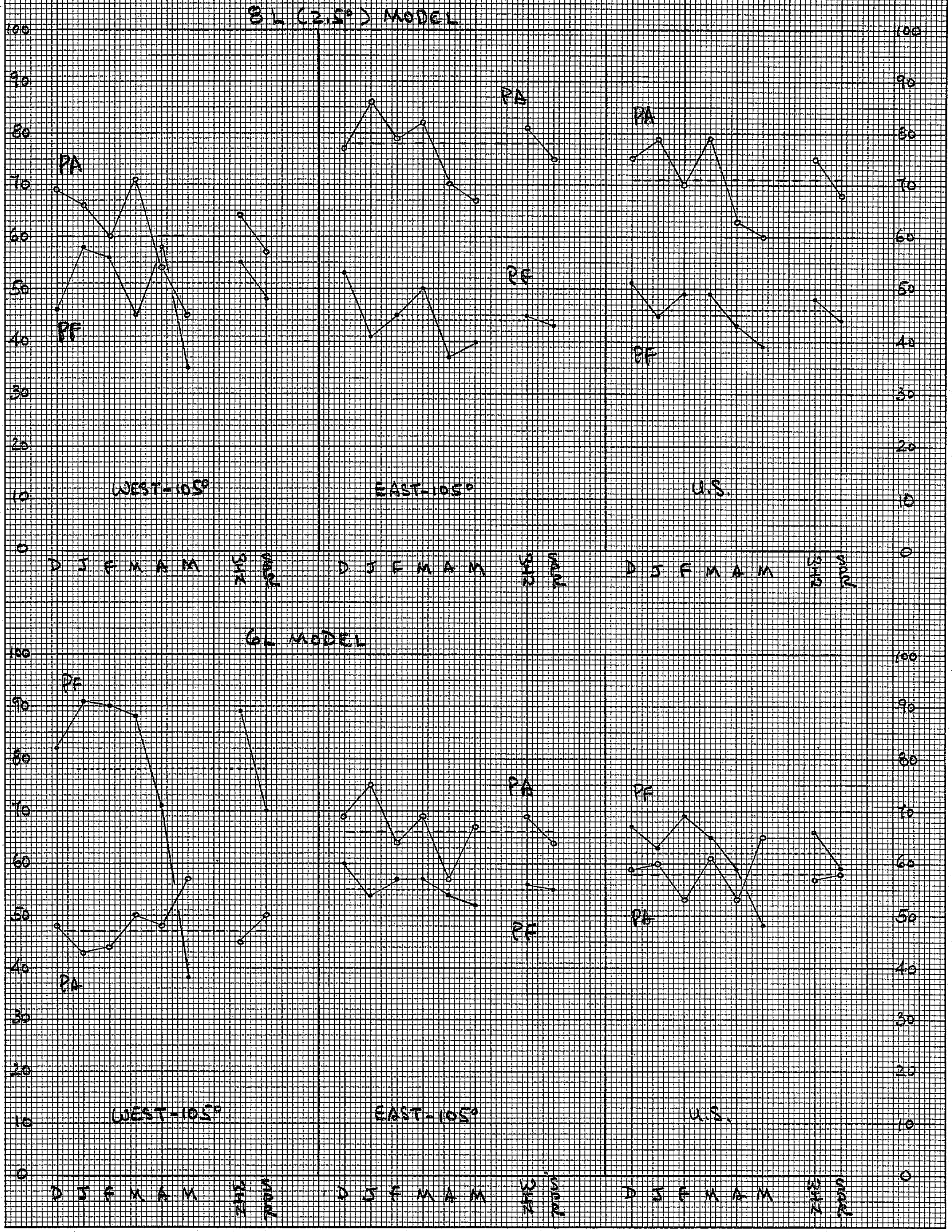
FIGURE VII(c)



PCPN VERIFICATION: LFM; 24 HR FCST; U.T. 00-12Z
WEST-105°
EAST-105°
U.S.
TSNP
TSP
BIAS
D J F M A M 3H2 Wave

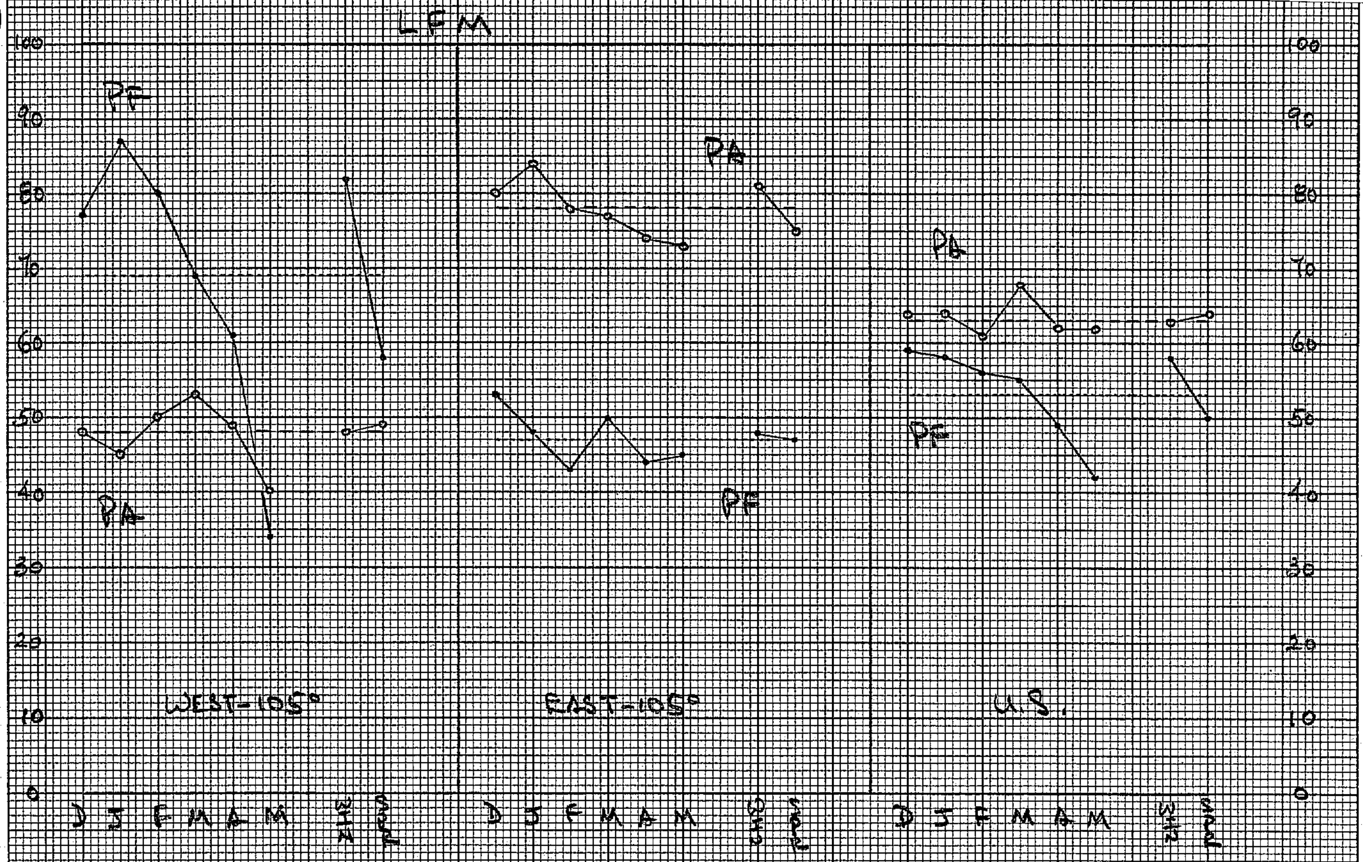
PCPN VERIFICATION: 24HR FCST; V.T. 00-12Z; PA (CIRCLE); PF (DOT)
BY MONTHS; SEASONS; TOTAL (PA-DASH; PF-DOT)

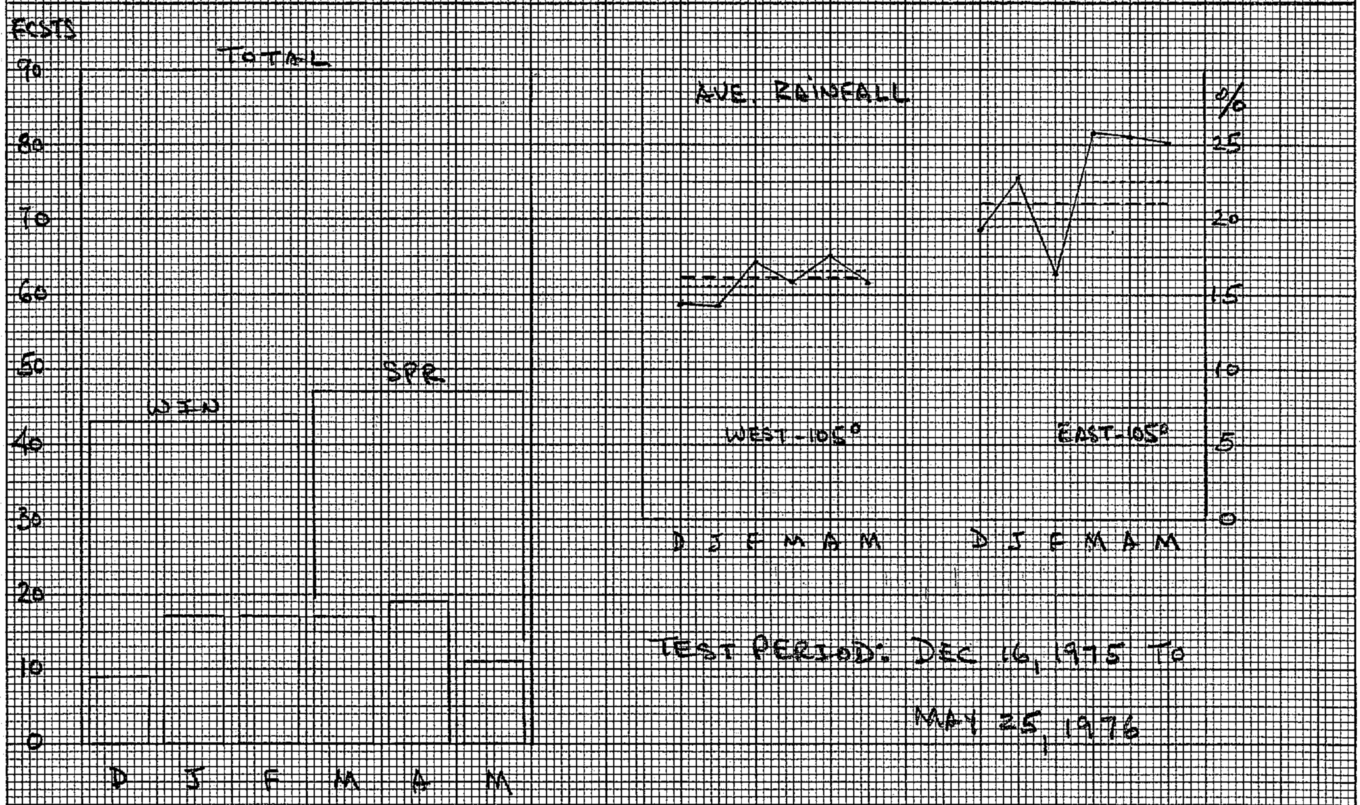
FIGURE VIII(a)



PCPN VERIFICATION: 24-HR FCST; V.T 00-12Z; PA (CIRCLE); PF (DOT)
BY MONTHS; SEASONS; TOTAL (PA - DASH; PF - DOT)

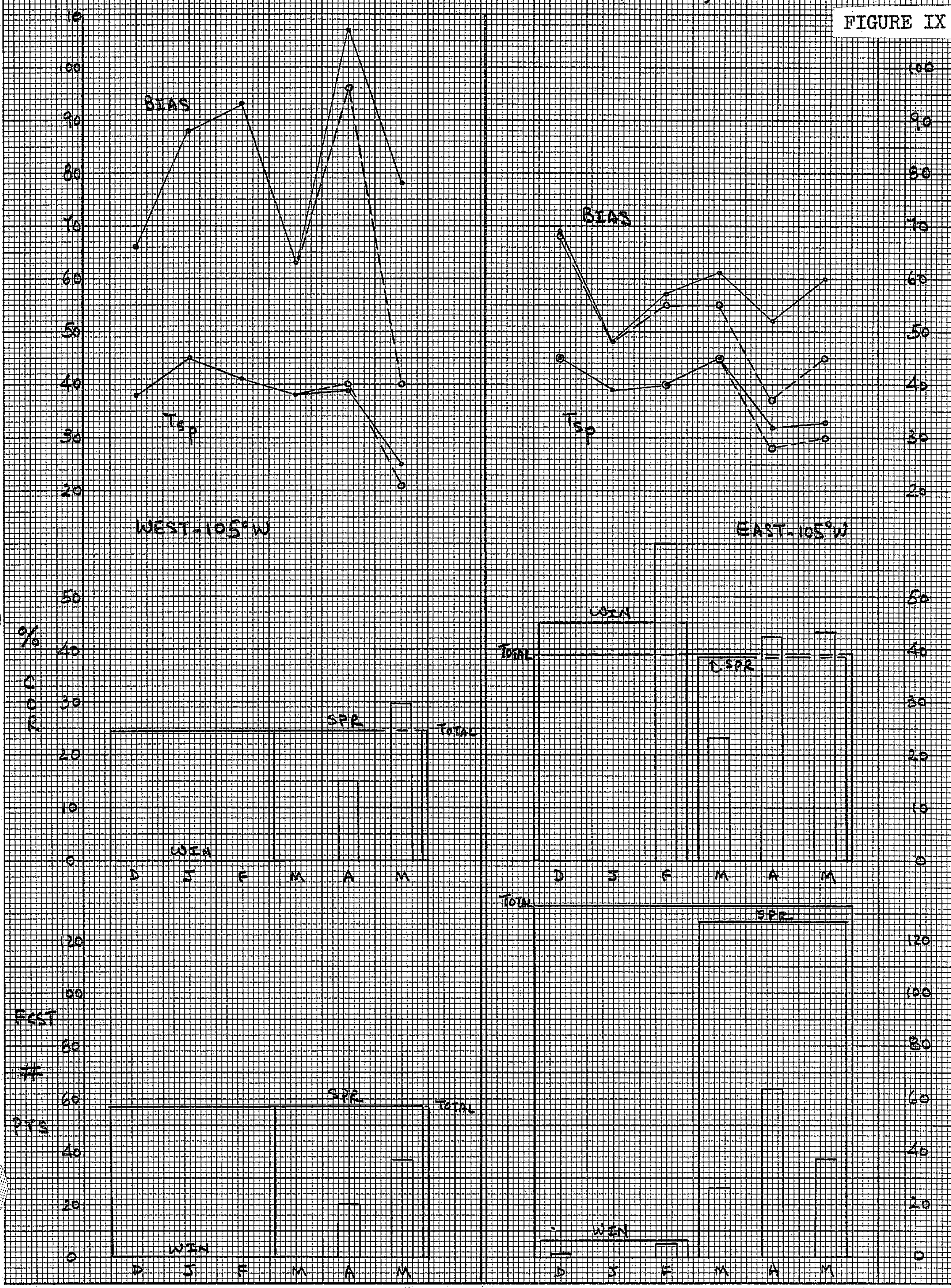
FIGURE VIII(b)





CONVECTIVE PCPN FCST PTS: 2.5° BL 24 HR FCST; 90 CASES (DEC 16, 1976 TO MAY 25, 1976); 167 PT GRID, SOLID (ALL PCPN); DASH (W/O CONVECTIVE)

FIGURE IX



10 X 10 TO THE CENTIMETER 18 X 25 CM.
UNITED CONVERTERS & PRINTERS